Surveying for hellbender salamanders, *Cryptobranchus alleganiensis* (Daudin): A review and critique

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Abstract. We review the wide array of techniques and their variants used in studying a cryptobranchid salamander and discuss their advantages and disadvantages. Electroshocking surveys are strongly discouraged because of the great potential for damaging reproductive success, immune systems, and their questionable effectiveness. Because successful *Cryptobranchus alleganiensis* nesting sites appear to be quite limited, the use of Peavy hooks and crowbars to breakup bedrock or dislodge large cover rocks should be restricted. Currently, skin-diving surveys coupled with turning objects is the only method shown to obtain all sizes of gilled larvae and multiple age groups of non-gilled and adult *C. alleganiensis* in brief periods.

Key words: *Andrias*; collecting; *Cryptobranchus*; ecology; hellbender; salamander; survey; technique.

Introduction

The family Cryptobranchidae includes only three extant species, the giant salamanders *Andrias davidianus* from China, *A. japonicus* from Japan, and hellbender, *Cryptobranchus alleganiensis* from central and eastern United States. Both Asiatic giant salamanders are protected within their respective countries. Additionally, *A. japonicus* is listed as Vulnerable by the IUCN (Nickerson, 2002). Hellbenders have been listed as endangered, threatened, species of special concern, or otherwise protected in most states throughout their range (Levell, 1995). Surveys have shown substantial declines in most populations where density was known, and population collapses in others (Trauth et al., 1992, 1993; Wheeler et al., 2003). The Ozark hellbender, *C. a. bishopi*, is a candidate for the U.S. Fish and Wildlife Service Threatened and Endangered species listing (USFWS, 2002). Because few or no ecological studies of *C. alleganiensis* have taken place in most states, we review

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previous survey methods and discuss their advantages and disadvantages to aid future studies, especially relating to conservation. Although this review focuses on *C. alleganiensis*, it is applicable to studies on all cryptobranchid salamanders.

Review

Williams et al. (1981) evaluated five known and potential sampling techniques for *C. alleganiensis*, including (1) walking a stream, search and seizure, (2) walking a stream and turning rocks with a rake, search and seizure, (3) electroshocking and dip netting, (4) seine herding, and (5) electroshocking with seining. Each of the five techniques was used for one hr each day within the same sample plot, with a one h interval between techniques (Williams et al., 1981). The sampling period was rotated so that each technique was applied once in each time period (01:00-10:00 and 15:00-24:00 hrs) during three five-day periods at each of three 200 m sample plots (Williams et al., 1981).

Turning rocks and other objects while wading has been the most widely used capture technique for *C. alleganiensis* (Peterson, 1987; Taber et al.,1975). At times, wading surveyors have used potato rakes to turn rocks, face masks to reduce surface glare, and dip-nets to scoop up *C. alleganiensis*. A peavy hook has been used to aid surveyors by alleviating the strain of bending and kneeling especially when lifting large rocks (Soule and Lindberg, 1994). Crowbars have also been used to break bedrock and expose secluded individuals (Peterson, 1988).

Researchers using the wading and turning technique have obtained large numbers of individuals from Ozark streams: 1,132 by Taber et al. (1975), 744 individuals by Peterson et al. (1983), and 1,208 individuals by Peterson et al. (1988). This technique is probably most effective in relatively clear water, $\leq$1.0 m in depth, with bottoms that have numerous rocks and other objects to turn. However, this method is often ineffective in capturing larvae and individuals $<$20 cm (Peterson et al., 1983; Nickerson, unpubl. data). Sweeping the area near and downstream from an overturned object with a dip net or placing a seine downstream may aid in the capture of these smaller individuals. Advantages are low equipment costs, quick sampling, and one surveyor can safely work alone. Disadvantages of this method include being unable to sample deep water, the potential for missing hellbenders because of glare reflected from the water's surface, rapid fatigue, and potential back injuries from constant bending over and lifting.

Skin-diving gear (i.e., a wet suit, face mask, snorkle, and fins or tennis shoes) coupled with turning rocks and logs has been a very successful method for capturing *C. alleganiensis* in Ozark waterways of Missouri and Arkansas (Nickerson and Mays, 1973a, b) and streams within the Great Smoky Mountains National Park (GSMNP) in Tennessee and North Carolina (Nickerson et al., 2000, 2002). Using this method, up to 96 individuals have been caught and released by a single person in one day (Nickerson, unpubl. data). Skin-diving surveys have produced many more gilled larvae than the wading and turning method in Ozark studies, even though skin-diving was implemented for a much shorter time (Nickerson et al., 2002). Brief skin-diving surveys obtained gilled larvae of all age classes, as well as multiple adult age groups, in GSMNP streams (Nickerson et al., 2002). Skin-diving is most efficient in clear waters from 0.5 to <3.0 m in depth. Advantages include absence of surface reflective glare, ease in turning heavy objects due to bouyant force, as well as affording closer proximity to exposed *C. alleganiensis*.

Although skin-diving is often a better method than "wading and turning", there are disadvantages. Equipment costs are considerably greater than wading and turning methods. Working alone may be hazardous in murky water, white water, cold water, and in areas of high boat traffic. Bodies of water with motorized boats may require diving buoys with dive flags. Diving during colder months may cause rapid loss of body heat necessitating the use of wet suits, which also provide protection from abrasion. A one h exposure to 10°C water in a 5 mm wet suit (farmer John style) has proven to be tolerable to many surveyors. However, a dry suit should be considered for prolonged work at cold temperatures. Dry suits are expensive and require more lead weight to counteract the increased bouyancy. Experienced dry suit divers have recommended that a diver should not enter water >2 m deep with a strong current, unless they have a compressed air source to inflate the suit. These divers suggest a very durable dry suit, perhaps composed of crushed neoprene because of the potential of tears and seal ripping caused by abrasion.

Like skin-diving gear, scuba gear (i.e., with air tanks) has been used effectively in large deep bodies of water (S.E. Trauth, pers. comm.). Scuba gear also has the added benefit of allowing the diver to stay submerged longer, thus reducing fatigue. Disadvantages of scuba are greater costs of equipment, dependency upon multiple tanks, a substantial compressor, diving buddy, and risks similar to skin-diving.

Many salamanders may be efficiently collected by seining, but the proclivity of *C. alleganiensis* for cover objects has limited the use of seines. Ichthyologists who study riffle fishes have collected larval *C. alleganiensis* by placing a seine in a strong riffle current and then raking or turning the gravel beds with their feet, upstream from the seine (L. Page, pers. comm.).

Hellbenders have also been taken by hand fishing, where one extends their arm under large rocks, into hollow logs or holes within banks until the hand comes into contact with the salamander, which is then grasped and removed (Nickerson, pers. obs.). The risks include not knowing exactly what one is grabbing and the chance of having an arm becoming lodged while holding your breath under water.

Electroshocking or electrofishing has been used to collect large aquatic salamanders by numerous investigators, including Fitch (1959), Shoop (1965), and Matson (1990). Electrofishing is typically used in shallow water, but is known to cause electrotetanus, electronarcosis, and electrotaxis (if using direct current; Reynolds, 1983). Its effectiveness varies among species due to tissue resistance, size, behavior, habitat, bottom substrate, and water conductivity (Reynolds, 1983). There is a great deal of variation in the types and applications of electroshocking equipment and performance under differing climatic conditions.

Williams et al. (1981: 26) concluded that "electroshocking was far superior than any other published method of sampling hellbender populations", and this technique was "the most effective and efficient technique for capturing hellbenders for population analysis". However, Williams et al. (1981) did not include the skin-diving method previously used by Nickerson and Mays (1973a, b). Furthermore, Williams et al. (1981) did not provide data on population structure, their experimental design required a minimum of three people in each sampling component, and they did not consider individual effort. Their sampling techniques exposed hellbenders to five potentially stressful events within each 9 h sampling period, including two electroshockings and a translocation or loss of shelter. These disruptions may have caused many *C. alleganiensis* to obtain less secure sites at the margins of typical shelters, making them more susceptible to electroshocking.

The Latin square-like experimental design of Williams et al. (1981) appears satisfactory on paper, however, other studies and observations disagree with their results and conclusions. For example, on 29 July 1970, a Missouri Department of Conservation (MDC) shocking crew conducted a diurnal survey of a 15 km section of the North Fork of White River and captured only a single *C. alleganiensis* (D. Campbell, pers. comm.). Yet, in only a 2.67 km portion within this same 15 km section, Nickerson and Mays (1973a, b) estimated the population to be between 341-573 hellbenders/km of stream-bed. Furthermore, upon following the MDC crew 5 km downstream, only two exposed hellbenders were observed (Nickerson, pers. obs.). Nocturnal electroshocking by a Milwaukee Public Museum (MPM) ichthyology group within this same 15 km river section, produced different fish taxa and species abundance, as compared to diurnal surveys and only one hellbender (G. Ludwig and D. Tills, pers. comm.). Tills et al. (1977) failed to collect any *C. alleganiensis* on multi-state electroshocking stream surveys that included known *C. alleganiensis* habitat.

Electroshocking surveys also failed to locate *C. alleganiensis* on the Susquehanna drainage in New York, while turning rocks was successful (Soule and Lindberg, 1994). A two-year population study of another large aquatic salamander, *Necturus maculosus*, in Ohio's Grand River, estimated more than 800 *N. maculosus*/km and concluded that electroshocking was totally ineffective in capturing these salamanders (Matson, 1990). The surveyed sections of Nickerson and Mays (1973a, b) and Matson (1990) had substantial rocky areas, and salamanders under these rocks either failed to receive enough stimulus to exit from beneath the rocks or remained there because of electrotetanus or electronarcosis. Possibly there was not enough flow to wash them out from under the rock.

The advantage of electroshocking is that given sufficient time and assuming appropriate conductivity, etc., *C. alleganiensis* can usually be coaxed out from under a rock in small streams and shallow water (N. Burkhead, pers. comm.). The disadvantages include high equipment costs, the application may require several surveyors, and there are potential dangers to both the animals and the surveyors. Nickerson et al. (2002) recommended against using electroshocking in stream sections with *C. alleganiensis* during the late summer and fall reproduction periods. The studies of Cho et al. (2002) are especially alarming and illustrated that (1) mature female chinook salmon, *Oncorhynchus ishawytscha*, electroshocked in a controlled environment with 10-s pulsed DC from a standard backpack shocker exhibited as much as 93% egg mortality, (2) shocked eggs mortality was as high as 34%, and (3) electroshocked juveniles had more spinal aberrations and physiological and immune effects than controls.

Anecdotal accounts indicate that *C. alleganiensis* is attracted to dead bait, and that the chemoreception of *C. alleganiensis* may allow them to sense some organic substances from considerable distances (Townsend, 1882; Nickerson and Mays, 1973a). *Cryptobranchus alleganiensis* were readily caught using bottom-set bank lines, in sections of the Eleven Point River, Oregon County, Missouri, which had no rocks or logs that could be turned (Wortham, 1970), and in quiet deeper stretches of Ozark streams at night (Dundee and Dundee, 1965). *Cryptobranchus alleganiensis* are routinely caught by fishermen (Beck, 1965) and fishermen using natural baits are considered the most devastating predator on adult *C. alleganiensis* in Indiana's Blue River (Kern, 1984). If the presence or absence of *C. alleganiensis* is a major study objective, baited lines should be considered in spite of hook injuries.

Baited traps also depend on chemo-reception and have shown mixed results. Wire mesh traps baited with chicken livers proved unsuccessful in a New York study (Soule and Lindberg, 1994). However, hoop-nets baited with cut sucker fish (Catostomidae) were successful in catching 29 *C. alleganiensis* in the Blue River, Indiana (Kern, 1984).

Sherman C. Bishop and others collected *C. alleganiensis* at night (Alexander, 1927), and many sportsmen have reported seeing *C. alleganiensis* during "rough fish" gigging sessions, which typically correlate with hellbender breeding season (Nickerson, unpubl. data). A seasonal activity study correlated *C. alleganiensis* nocturnal activity with higher water levels and showed nocturnal surveys useful for documenting presence only in May and June (Humphries and Pauley, 2000). *Cryptobranchus alleganiensis* have very low metabolisms and do not require frequent feeding unless resources are sparse (V. Hutchison, pers. comm.; F. Binkowski and M. Nickerson, unpubl. data; Nickerson, 1980). Several studies have shown that *C. alleganiensis* usually do not move great distances and have small home ranges with small mean activity radiuses (Hillis and Bellis, 1971; Nickerson and Mays, 1973a, b; Coatney, 1982). The unique suction feeding of cryptobranchids (Cundall et al., 1987) is well adapted for sit and wait feeding. Therefore, nocturnal sojourns for food are probably quite limited.

Conclusions

In summation, researchers need to link the goals of their study and the ecological conditions of habitats with the technique(s) chosen. We are convinced that electroshocking is not the most effective and efficient technique for *C. alleganiensis* population analysis within most of the habitats where we have conducted studies. Wading shallow water and turning rocks is an effective way to collect substantial numbers of *C. alleganiensis* quickly, but may be greatly limited in collecting larval and small hellbenders <20 cm. However, kneeling in shallow water using a face mask coupled with turning small rocks and other objects, larvae and small *C. alleganiensis* may be more readily located. Currently skin-diving is the only method shown to produce all sizes of gilled larvae and multiple age groups of non-gilled and adult *C. alleganiensis* within brief sampling periods. We recommend against using electroshocking to survey for *C. alleganiensis* because of the great potential for damaging their reproductive success and immune systems. We also recommend against the extensive use of peavy hooks or crowbars to breakup bedrock or dislodge substantial areas of large cover rocks. Instead we suggest the use of a fiber optic camera system to probe under large rocks and into bed-rock crevices to locate *C. alleganiensis*. Although this is a far more costly approach, it may protect preferred nesting sites in areas where successful sites may be quite limited.

Acknowledgments. We thank Noel Burkhead, C. Kenneth Dodd, Jr., George H. Burgess, Kelly J. Irwin, and Stan Trauth for their input, and two anonymous reviewers for their constructive criticism. The Reptile and Amphibian Corps (RACC) provided partial funding for this study.

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Accepted: October 24, 2002.